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# UNIVERSITI SAINS MALAYSIA

Second Semester Examination  
Academic Session 2004/2005

March 2005

## **EBB 210E/2 – Process Control** **[Kawalan Proses]**

Duration: 2 hours  
[Masa: 2 jam]

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Please check that this examination paper consists of TWELVE pages of printed material before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA BELAS muka surat bercetak sebelum anda memulakan peperiksaan].*

This paper contains FIVE questions.

*[Kertas soalan ini mengandungi LIMA soalan].*

**Instructions:** Answer **FOUR** questions. If a candidate answer more than four questions, only the first four answered will be examined and awarded marks.

**[Arahan:** Jawab **EMPAT** soalan. Jika calon menjawab lebih daripada empat soalan hanya empat soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah].

Answer to any question must start on a new page.

*[Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru].*

All questions must be answered in English. However, ONE question can be answered in bahasa Malaysia.

*[Jawab semua soalan dalam bahasa Inggeris. Walau bagaimanapun, SATU soalan dibenarkan dijawab dalam bahasa Malaysia].*

1. (a) Complete the partial fraction expansion and find the inverse Laplace transformation of each of the following functions:

i.  $Y(s) = \frac{1}{s^2 + s + 1}$

ii.  $Y(s) = \frac{(s+2)(s+3)}{(s+4)(s+5)(s+6)}$

iii.  $Y(s) = \frac{12(s+2)}{s(s^2+9)}$

(35 marks)

*Lengkapkan pengembangan pecahan separa dan penjelmaan Laplace songsang bagi setiap fungsi di bawah:*

i.  $Y(s) = \frac{1}{s^2 + s + 1}$

ii.  $Y(s) = \frac{(s+2)(s+3)}{(s+4)(s+5)(s+6)}$

iii.  $Y(s) = \frac{12(s+2)}{s(s^2+9)}$

(35 markah)

- (b) Redo the problems above by writing the Matlab Command to obtain:

- i. the partial fraction expansion
- ii. the inverse Laplace transformation

(30 marks)

*Ulang semula soalan di atas dengan menggunakan arahan Matlab untuk mendapatkan:*

- i. pengembangan pecahan separa
- ii. penjelmaan Laplace songsang

(30 markah)

...3/-

- (c) The spring-mass-damping system shown in the figure below is described by the following differential equation:

$$m \frac{d^2 x}{dt^2} + R \frac{dx}{dt} + Kx = f$$

where:

$m$  = mass, kilogram

$R$  = dashpot resistance, newton/(meter/second)

$K$  = spring constant, newton/meter

$X$  = position of the mass, meter

$F$  = external force applied to the mass, newton

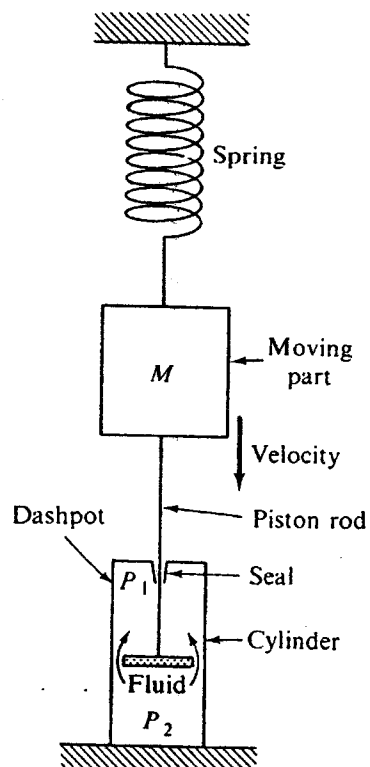
Determine the transfer function,  $X(s)/F(s)$ , if

$$m = 3.2 \text{ kg}$$

$$R = 2.0 \text{ N/(m/s)}$$

$$K = 800 \text{ N/m}$$

(35 marks)



A mechanical part with resistance provided by a dashpot

...4/-

Sistem pegas-jisim-redaman di dalam rajah di bawah ini diuraikan melalui persamaan kebeza berikut:

$$m \frac{d^2 x}{dt^2} + R \frac{dx}{dt} + Kx = f$$

dimana:

$m$  = jisim, kilogram

$R$  = rintangan daspot, Newton / (meter/saat)

$K$  = pemalar spring, newton/meter

$X$  = kedudukan jisim, meter

$F$  = daya luar yang dikenakan pada jisim, newton

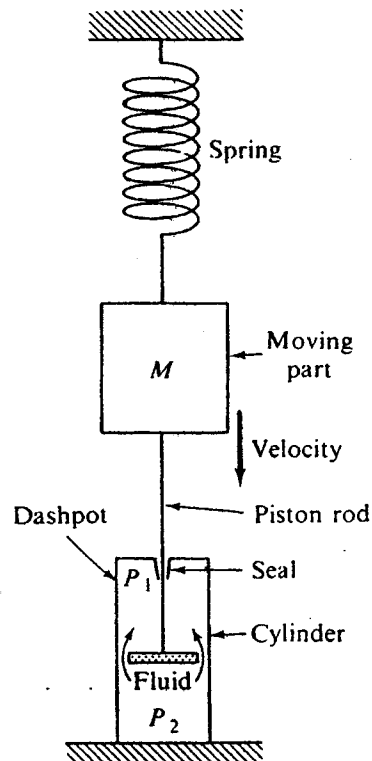
Tentukan fungsi pindah,  $X(s)/F(s)$ , jika

$$m = 3.2 \text{ kg}$$

$$R = 2.0 \text{ N/(m/s)}$$

$$K = 800 \text{ N/m}$$

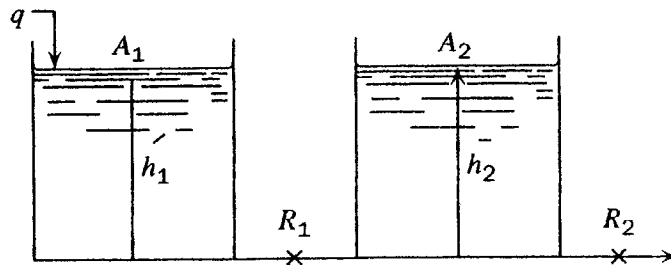
(35 markah)



A mechanical part with resistance provided by a dashpot

...5/-

2. (a) The two tanks shown in the figure below are connected in an interacting fashion. The system is initially at steady state with  $q = 10$  cfm. The following data apply to the tanks:  $A_1 = 1 \text{ ft}^2$ ,  $A_2 = 1.25 \text{ ft}^2$ ,  $R_1 = 1 \text{ ft/cfm}$ ,  $R_2 = 0.8 \text{ ft/cfm}$ .
- If the flow changes from 10 to 11 cfm according to a step change, determine  $H_2(s)$ , i.e., the Laplace transform of  $H_2(t)$ , where  $H_2$  is the deviation in  $h_2$ .
  - Determine  $H_2(t=1)$ ,  $H_2(t=4)$  and  $H_2(t=\infty)$ .
  - Determine the initial levels (actual levels)  $h_1(t=0)$  and  $h_2(t=0)$  in the tanks.
  - Obtain an expression for  $H_1(s)$  for the unit-step change described above.



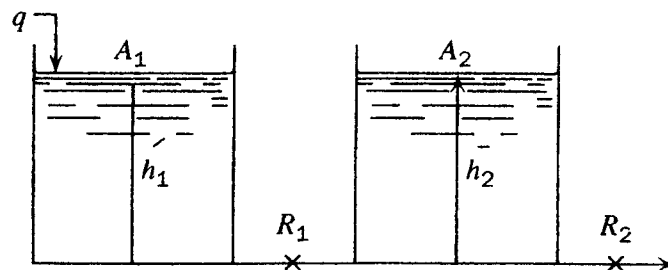
(70 marks)

- (b) Write down the necessary Matlab commands to obtain the plot of the response function in the time domain for the above interacting series system with the indicated step change forcing function

(30 marks)

Dua tangki yang ditunjukkan di dalam rajah di bawah telah disambungkan di dalam bentuk saling tindakan. Pada mulanya sistem tersebut berada di dalam keadaan mantap dengan  $q = 1$  cfm. Data-data berikut telah dikenakan pada tangki-tangki tersebut:  $A_1 = 1 \text{ ft}^2$ ,  $A_2 = 1.25 \text{ ft}^2$ ,  $R_1 = 1 \text{ ft/cfm}$ ,  $R_2 = 0.8 \text{ ft/cfm}$ .

- Jika aliran bertukar daripada 10 kepada 11 cfm disebabkan oleh bertukar langkah, tentukan  $H(s)$ , iaitu jelmaan Laplace bagi  $H_2(t)$ , dimana  $H_2$  ialah sisihan dalam  $h_2$ .
- Tentukan  $H_2(t=1)$ ,  $H_2(t=4)$  dan  $H_2(t=\infty)$ .
- Tentukan aras mula (aras sebenar)  $h_1(t=0)$  dan  $h_2(t=0)$  di dalam tangki-tangki.
- Dapatkan ungkapan bagi  $H_1(s)$  bagi perubahan langkah-unit yang telah diuraikan di atas.



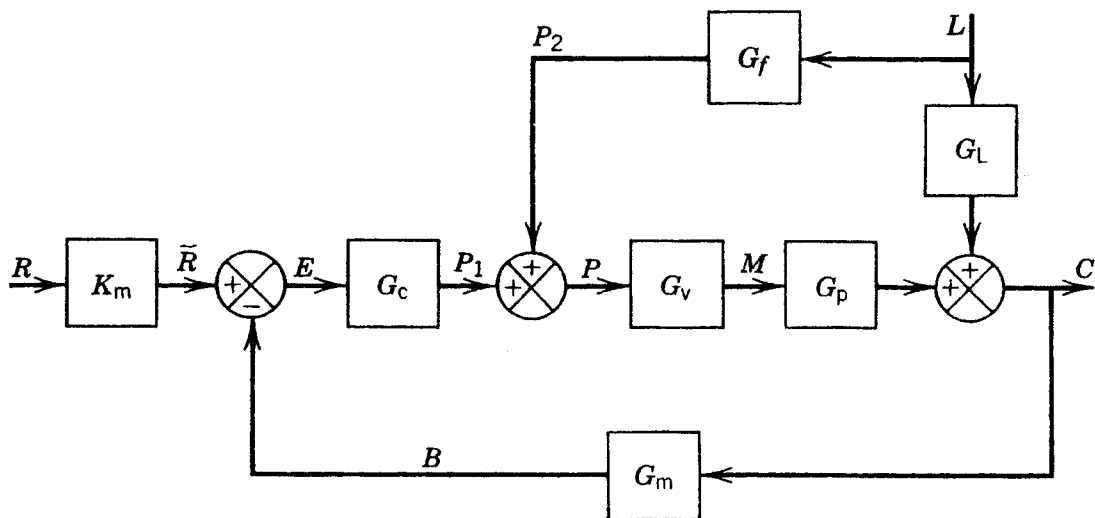
(70 markah)

Senaraikan arahan-arahan Matlab yang bersesuaian untuk mendapatkan plot bagi fungsi sambutan di dalam domain masa bagi sistem siri saling tindakan di atas dengan menunjukkan fungsi memaksa perubahan langkah.

(30 markah)

3. (a) A block diagram of a feedforward-feedback control system is shown in the drawing where  $G_f$  is the feedforward controller transfer function.

- i. Derive an expression for the closed-loop transfer function for load changes,  $C(s) / L(s)$ .
- ii. Assume that perfect control is desired for load changes, that is,  $C(s) = 0$  when  $L(s) \neq 0$ . Derive an expression for the ideal feedforward controller transfer function  $G_f$  that will theoretically provide perfect control.



Given:

$$G_f = \frac{1}{5s+1}$$

$$G_v = \frac{3.57}{5s+1}$$

$$G_L = \frac{80}{20s+1}$$

$$G_p = \frac{0.128}{60s+1}$$

$$G_c = 0.8$$

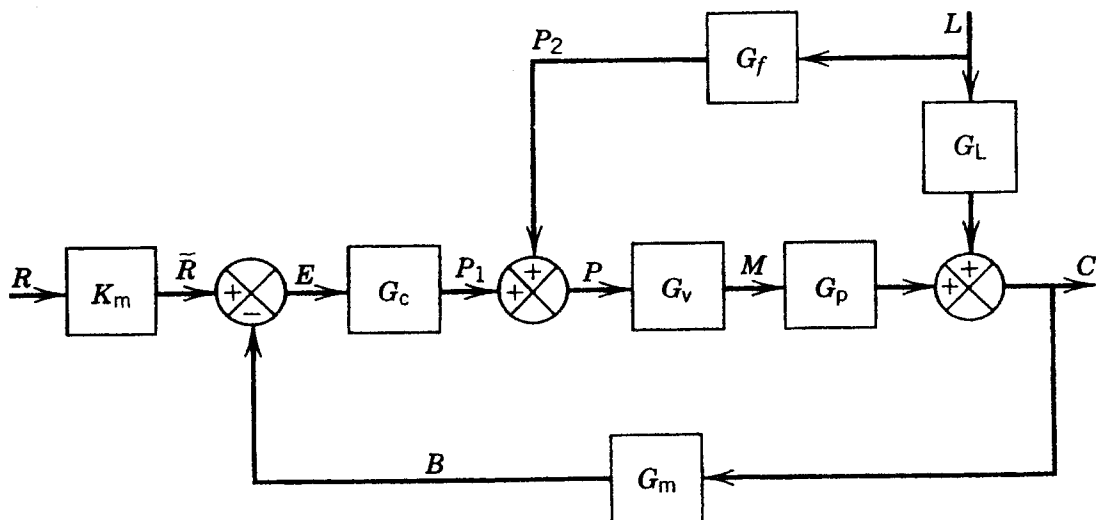
$$G_m = \frac{1.2}{25+1}$$

(70 marks)

...8/-

Gambarajah blok sistem kawalan suap depan-suap balik ditunjukkan di dalam lakaran di mana  $G_f$  adalah fungsi pindah pengawal suap depan.

- Terbitkan ungkapan fungsi pemindahan gelung tertutup bagi perubahan beban,  $C(s) / L(s)$ .
- Andaikan kawalan sempurna diperlukan untuk perubahan beban, iaitu,  $C(s) = 0$  apabila  $L(s) \neq 0$ . Terbitkan ungkapan bagi fungsi pemindahan pengawal suap depan unggul  $G_f$  yang akan menghasilkan kawalan sempurna secara teori.



Diberi:

$$G_f = \frac{1}{5s+1}$$

$$G_v = \frac{3.57}{5s+1}$$

$$G_L = \frac{80}{20s+1}$$

$$G_p = \frac{0.128}{60s+1}$$

$$G_c = 0.8$$

$$G_m = \frac{1.2}{25s+1}$$

(70 markah)

...9/-



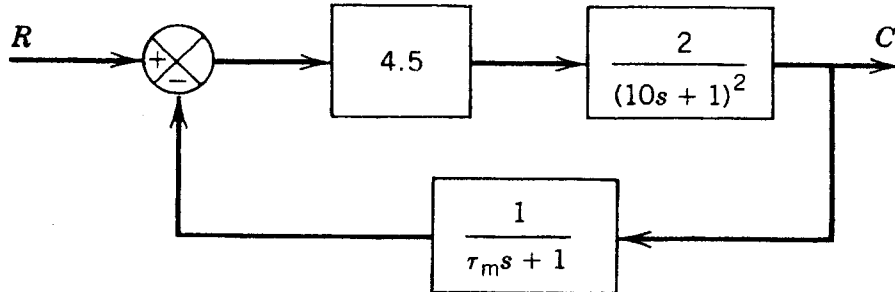
- (b) If the load changes occur as oscillatory function:  $\sin(0.3t)$ , how would you use Matlab to obtain the response plot in the time domain.

(30 marks)

*Jika perubahan beban berlaku secara fungsi ayunan (oscillatory function),  $\sin(0.3t)$ , bagaimanakah anda menggunakan Matlab untuk mendapatkan plot sambutan di dalam domain masa.*

(30 markah)

4. (a) A second-order process plus measuring element is controlled by a proportional controller as shown in the drawing.



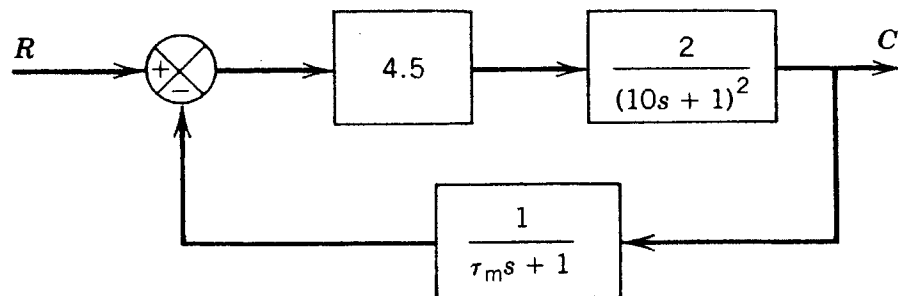
- i. For what range(s) of  $\tau_m$  will the resulting system be stable?
- ii. What practical arguments might be used to restrict the range(s) of acceptable  $\tau_m$  even further?
- iii. If a proportional-derivative controller with  $\tau_D = \tau_m$  is used, how would your answers to (a) and (b) be affected?

(70 marks)

- (b) Write down the Matlab commands to obtain the transfer function for the feedback closed-loop system by specifying  $\tau_m = 3.0$ .

(30 marks)

*Proses tertib-kedua serta elemen pengukuran di kawal menggunakan pengawal berkadaran sebagaimana ditunjukkan di dalam lakaran*



- i. *Berapakah julat  $\tau_m$  akan menghasilkan sistem yang stabil?*
- ii. *Apakah hujah yang praktikal yang boleh digunakan untuk menghadkan julat boleh terima  $\tau_m$ ?*
- iii. *Jika kawalan terbitan berkadaran dengan  $\tau_D = \tau_m$  digunakan, bagaimana jawapan tersebut memberi kesan kepada (i) dan (ii).*

*(70 markah)*

*Tunjukkan arahan-arahan Matlab untuk mendapatkan fungsi pindah bagi sistem gelung-tertutup suap balik dengan mengkhususkan  $\tau_m = 3.0$ .*

*(30 markah)*

5. (a) Construct a root-locus diagram of the control system with the following open-loop transfer function:

$$G(s)H(s) = \frac{10K}{s^2 + 20s + 16}$$

Determine the value of K that will produce a damping ratio of 0.8.

(70 marks)

- (b) Taking K=9.0, write down the 2 (two) methods of the Matlab command to plot the root locus diagram of the above control system.

(30 marks)

*Bina gambarajah Londar punca (root-Locas) bagi sistem kawalan dengan fungsi pindah gelung terbuka berikut:*

$$G(s)H(s) = \frac{10K}{s^2 + 20s + 16}$$

*Tentukan nilai K yang akan memberikan julat nisbah redaman 0.8.*

*(70 markah)*

*Ambil K=9.0, tunjukkan dua kaedah arahan Matlab untuk memplot gambarajah londar punca (root-locas diagram) bagi sistem kawalan di atas.*

*(30 markah)*